AL/OE-TR-1996-0088

FEASIBILITY ANALYSIS OF A NOISEMAP CALCULATION PROCEDURE FOR HELICOPTER AND VTOL AIRCRAFT NOISE EXPOSURE

ARMSTRONG LABORATORY

Robert A. Lee

Noise Effects Branch
Wright-Patterson Air Force Base, OH

Dave Brown
Carey L. Moulton

Wyle Research
128 Maryland St.
El Segundo, CA 90245

OCCUPATIONAL AND ENVIRONMENTAL HEALTH DIRECTORATE
Bioenvironmental Engineering Division
Noise Effects Branch
2610 7th Street
Wright-Patterson Air Force Base OH 45433-7901

June 1996

Final Technical Report for Period May 1993 to February 1994

Approved for public release; distribution is unlimited.

AIR FORCE MATERIEL COMMAND
BROOKS AIR FORCE BASE, TEXAS

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Armstrong Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
8725 John J. Kingman RD., STE 0944
Ft Belvoir, VA 22060-6218

DISCLAIMER

This Technical Report is published as received and has not been edited by the Technical Editing Staff of the Armstrong Labortory.

TECHNICAL REVIEW AND APPROVAL

AL/OE-TR-1996-0088

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Robert A. Lee

ROBERT A. LEE
Chief, Noise Effects Branch

FOR THE DIRECTOR

James D. Montgomery

JAMES D. MONTGOMERY, LT COL, USAF, BSC
Chief, Bioenvironmental Engineering Division
Armstrong Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
June 1996

3. REPORT TYPE AND DATES COVERED
Interim report for May 1993 thru February 1994

4. TITLE AND SUBTITLE

FEASIBILITY ANALYSIS OF A NOISEMAP CALCULATION PROCEDURE FOR HELICOPTOR AND VTOL AIRCRAFT NOISE EXPOSURE

5. FUNDING NUMBERS

PE: 62202F
PR: 7757
TA: C2
WU: 01

6. AUTHOR(S)

D. Brown and C. L. Boulton of Wyle Research

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Wyle Research
128 Maryland St.
El Segundo CA 90245

8. PERFORMING ORGANIZATION REPORT NUMBER

WR 94-3

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Armstrong Laboratory, Occupational & Environmental Health Directorate
Bioenvironmental Engineering Division
Noise Effects Branch
2610 7th Street
Wright-Patterson AFB OH 45433-7901

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AL/OE-TR-1996-0088

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

A

13. ABSTRACT *(Maximum 200 words)*

The current NOISEMAP programs, including BASEOPS, Master Control Module (MCM), OMEGA 10 and 11 and NOISEMAP/NOISEFILE, are tailored to be applicable to fixed-wing aircraft operations and corresponding maintenance run-ups at airbases with runways. The programs can be and have been used for helicopter operations but are not well suited to this use in their present form. It is recommended that NOISEMAP be adapted to include an optional selection of helicopter applicability, the results of which can be noise contour plotted as a stand-alone case or in conjunction ("energy-added") with other fixed-wing aircraft cases It is recommended that the NOISEMAP development be performed in two phases: Phase1 would include revisions to BASEOPS, MCM and NOISEMAP to allow current NOISEFILE helicopter data to be better and most conveniently utilized for assembling and running helicopter operational cases. These revisions would include assembling a standardized set of helicopter operating conditions for which SEL versus distance files can be generated by OMEGA 10 and 11 by reference to the existing NOISEFILE data. Phase 2 would be an upgrade to the Phase 1 program to include refinements specific to helicopter noise, such as in-flight directivity effects, modified lateral attenuation models, an enhanced database for additional power/flight conditions (to replace surrogate files) and an increased compatibility with the DOT/FAA Heliport Noise Model.

14. SUBJECT TERMS

Acoustics	Aircraft Noise
Environmental Noise	Helicopter Noise
Psychoacoustics	Environmental Impact

15. NUMBER OF PAGES
28

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89) Prescribed by ANSI Std Z-39-18
298-102 COMPUTER GENERATED

SUMMARY

The current NOISEMAP programs, including BASEOPS, Master Control Module (MCM), OMEGA 10 and 11 and NOISEMAP/NOISEFILE, are tailored to be applicable to fixed-wing aircraft operations and corresponding maintenance run-ups at airbases with runways. The programs can be and have been used for helicopter operations but are not well suited to this use in their present form.

It is recommended that NOISEMAP be adapted to include an optional selection of helicopter applicability, the results of which can be noise contour plotted as a stand-alone case or in conjunction ("energy-added") with other fixed-wing aircraft cases.

It is recommended that the NOISEMAP development be performed in two phases:

- Phase 1 would include revisions to BASEOPS, MCM and NOISEMAP to allow current NOISEFILE helicopter data to be better and most conveniently utilized for assembling and running helicopter operational cases. These revisions would include assembling a standardized set of helicopter operating conditions for which SEL versus distance files can be generated by OMEGA 10 and 11 by reference to the existing NOISEFILE data. These would serve as temporary (surrogate) files on flight conditions addressable through the BASEOPS program. The MCM would contain a set of "look-up tables" which would serve as a temporary "surrogate-generator" for OMEGA input deck definitions and adjustments. The main technical elements of NOISEMAP, NOISEFILE, OMEGA and contour plotting processes would be retained, including current LINEX, TURNEX, Lateral Attenuation and noise metric computational procedures.

- Phase 2 would be an upgrade to the Phase 1 program to include refinements specific to helicopter noise, such as in-flight directivity effects, modified lateral attenuation models, an enhanced database for additional power/flight conditions (to replace surrogate files) and an increased compatibility with the DOT/FAA Heliport Noise Model. It is envisioned that the NOISEMAP/HNM technologies for helicopter noise would rapidly converge, provided that new procedures for addressing ground cover, topography and barrier effects in each of the models are of similar form.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

NOISEMAP (Ref. 1) has been developed by the Air Force to provide an analytical procedure for the estimation of noise exposure levels around airbases. The procedure currently applies to fixed wing aircraft operating from runways and to engine maintenance operations involving power run-up at outdoor pads, test cells, hush houses, dynamometers or aircraft tie-down areas. Helicopter noise level (reference) data have been included in the database (NOISEFILE) for some time, and have recently been augmented by additional data from FAA and CERL measurement programs. These helicopter noise data are not, however, readily usable by NOISEMAP in a manner appropriate to VTOL operational procedures and are therefore subject to severe limitations in noise exposure estimation accuracy. In order to correct this limitation, it would be necessary to develop and invoke a revised version of NOISEMAP, inclusive of revised versions of BASEOPS, OMEGA 10 and OMEGA 11 and the Master Control Module (MCM) programs. Before embarking on such a development project it is astute to examine other currently available procedures for VTOL aircraft noise estimation and to determine whether they might have a direct influence on the NOISEMAP project, either by their adoption in entirety or in part. Key examples of these procedures are:

- SAE AIR 1989 (May 1989) "Helicopter External Noise Estimation," Ref. 2,
- CERL TR N-186 (August 1984) "Prediction and Modeling of Helicopter Noise," Ref. 3,
- DOT/FAA/EE-88-2 (February 1988) "Heliport Noise Model Version 1, User's Guide," Ref. 4,
- NASA LaRC, "ROTONET System," Phase 1, 1986; Phase 2, 1987 (Ref. 5).

In addition, the possibility of using the NOISEMAP technology program to estimate heliport noise exposures has been previously examined by Galloway in 1979 (Ref. 6). Specific recommendations were made at that time for the inclusion in NOISEMAP of some features unique to helicopter noise. These have not been implemented so far.

Of paramount importance to the development of a NOISEMAP procedure for VTOL aircraft noise is, of course, the availability of a reference noise level database for helicopters and other VTOL aircraft, especially military VTOL aircraft. One of the first compilations of helicopter noise data by means of a unified measurement and analysis procedure was

performed for the U.S. Army in 1970 (Ref. 7 and 8) for five army helicopters (AH-1G, CH-54, CH-47, UH-1B and OH-6). These measured data were acquired for purposes other than environmental analyses, but were suited to evaluation for level flyover and hover noise signatures in any of a wide range of noise metrics. Later Army (CERL) noise measurement programs were more specifically addressed to the environmental noise impact problem which the army addresses as the ICUZ (Installation Compatible Use Zoning) process. These included a standardized (Ref.9) noise measurement program on eight army helicopters on 1974 at Fort Rucker (Ref. 10) which in 1974 provided reference noise level data in terms of Sound Exposure Level versus distance tabulations for OH-58, AH-1G, UH-1M, UH-1H, UH-1B, CH-47B, CH-54, TH-55 helicopters in level flyover, nap-of-the-earth, ascent, descent, landing, takeoff and maneuver flight conditions. The project concluded that environmental noise data could be summarized (in SEL versus distance curves or tabulations) for all helicopters as

(a) level flyovers,

(b) inside and outside turns combined,

(c) ascents and descents combined,

although level flyover data, irrespective of loading (with/without troops, equipment, etc.) could be adequate for noise impact purposes.

Further data on Army helicopters was provided by measurement programs on UH-60A and CH-47C helicopters in 1982 (Ref. 11) and in a more recent measurement program on OH-58D Army helicopters in 1992 (Ref. 12).

In parallel with these Army programs, the Federal Aviation Administration (FAA) has developed a noise level database for (mainly) civilian helicopters in accordance with a Rotorcraft Master Plan (Ref. 13). These measurement programs resulted in a series of reports containing reference noise level data suitable for environmental impact assessments. A major compilation of available data was issued in 1982 by the FAA (Ref. 14) for a total of fifteen different helicopters, mostly civilian, and in a subsequent series of seven data/analyses reports (Ref. 15 through 21) covering a further seven helicopters.

All of these data have been reduced to SEL versus distance curves (tables) for use in the FAA's Heliport Noise Model (HNM).

Most of the data, including those from the DOT/FAA tests of 1980, the CERL tests and the more recent series of DOT/FAA tests have been converted to NOISEMAP/NOISEFILE format for use in NOISEMAP contour development. Eight of these helicopters were represented in the older versions of NOISEFILE under COMDECK data files 603 through 610 based on OMEGA 6 analysis conducted in 1980. Data for a further twenty-three helicopters have been recently added in NOISEFILE 6.3 as COMDECK data files 611 through 665 based on OMEGA 6 analyses conducted in 1992. These data comprise one-third octave band sound pressure level data at a reference distance (250 ft or 1000 ft) for specific flight conditions. Ground run-up directivity noise data are contained in NOISEFILE 6.3 as COMDECK data files 611 through 621 for eleven helicopter types.

As a final introductory note, procedures for the measurement of noise from military helicopters have recently been standardized by agreements between the U.S. Air Force, CERL and the U.S. Army Environmental Hygiene Agency (Ref. 22, 1990) and by the NATO Defense Departments representing Denmark, Germany, Norway, Switzerland, United Kingdom and United States (Ref. 23, 1993). These standardizations indicate a strong emphasis towards developing a more specific and reliable procedure for military helicopter (and other VTOL aircraft) noise impact analyses.

This report examines the needs of such development based on usage of existing NOISEMAP technology with revised and added components.

2.0 *BASIC REQUIREMENTS*

2.1 *Noise Database Enhancements*

NOISEFILE, the reference database for the NOISEMAP programs, contains a set of twenty-four one-third octave band sound pressure level data for each aircraft flight condition at a specified reference (air-to-ground) distance. These data are processed by OMEGA 10 to provide a set of sound level (SEL, EPNL, L_{Amax}, etc.) versus slant range distance tabulations for air-to-ground and ground-to-ground propagation. Static or ground-based stationary sources, such as helicopter in hover, are contained in a separate section of NOISEFILE and have a reference one-third octave band spectrum for each azimuthal angle at 10 degree intervals from 0° to 180°, which can be processed by OMEGA 11 to provide a set of sound level (L_A, PNL, etc.) versus slant range distance versus directivity angle data for ground-to-ground propagation only.

Two separate enhancements of these capabilities may be worthy of consideration for the helicopter/VTOL component of NOISEMAP. These are

- in-flight directivity, and
- hard and soft ground propagation.

Due to current development of capability to include topography as a feature of NOISEMAP calculations, it is assumed that the frequency based NOISEFILE and OMEGA 10, 11 functionality will be retained for helicopter noise computations.

2.1.1 <u>In-Flight Directivity</u>

In-flight directivity is usually embedded within the single event noise metric usage for aircraft flyover conditions. The SEL, for example, of a flyover noise event encompasses all of the temporal and directional variations of the noise during the event. However, helicopter noise is somewhat unique in that it has different directional characteristics on the left, center and right sidelines due to main and tail rotor noise asymmetries, relative to the flight path. Whether these are significant enough to be of relevance in environmental impact studies is arguable.

Review of the FAA's HNM database (Ref. 4) shows that differences between left, center and right SEL values vary considerably among the various (15) helicopter types and also

among takeoff, approach and level flight conditions (Table 2-1). At worst, the levels vary up to 7.5 dB between left, center and right, the more typical imbalance being of the order of 3 to 5 dB at some point in the SEL versus distance curves.

Helicopter data contained in the most recent NOISEFILE do not contain separate files for the left, center and right directions and are an average of measured noise data from the same tests as the HNM data.

It is therefore proposed that the initial versions of the NOISEMAP helicopter noise calculation procedure do not differentiate between in-flight directivity differences and that this be examined in environmental impact studies to establish whether a need exists for military uses.

2.1.2 *Hard Versus Soft Ground Propagation*

The ability to include topography in the NOISEMAP computational procedure for fixed-wing aircraft noise propagation would of course be extended to helicopter noise. This ability is currently being developed by AAMRL and will be available in future NOISEMAP releases.

It is not, therefore, seen as a high priority that some interim version of a calculation procedure for ground impedance effects should be created solely for helicopter noise. This would be accommodated by OMEGA 11 for ground-to-ground propagation of ground-idle, taxi or hover noise emissions.

2.1.3 *Additional Data Files*

Table 2-2 shows the helicopter types which are represented in the current flyover data in NOISEFILE, together with additional types that can be abstracted from HNM files if necessary. As is evident, all of the files include level flyover noise data but not necessarily approach, takeoff or hover (in or out of ground effect) conditions. Some files (not shown) also contain ground idle noise data. In the long term it would be advisable to have a consistent set of files covering a standard set of reference flight conditions. This would facilitate the description of flight profiles in the BASEOPS program, such as those illustrated in Figure 2-1.

As an interim measure it is recommended that surrogate files be developed for the missing conditions, based on data trends available from the original flight test reports or from other sources such as Ref. 14. This would introduce some uniformity in usage of NOISEMAP

Table 2-1

Maximum Difference Between Left/Center/Right SEL
Values in HNM Helicopter Noise Data (Ref. 4)

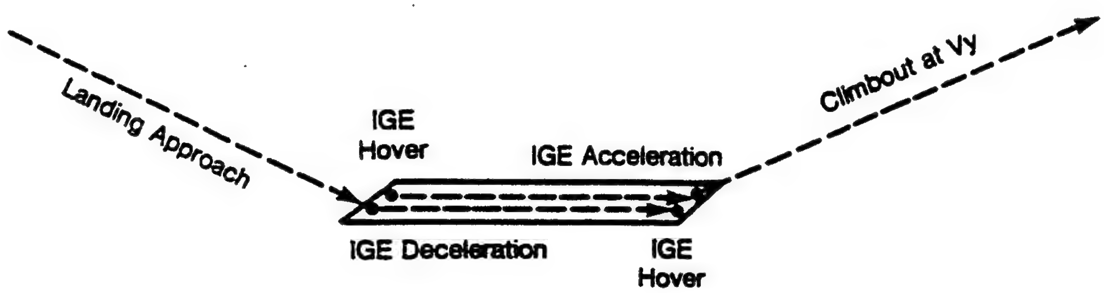
Helicopter Type			Takeoff	Approach	Level (Right)
Bell 212			3.5	4	2.7
S-61 (CH3A)			3.5	2.7	3
CH-47D			0.8	4.6	1.9
Hughes 500D			2.9	2.3	2.1
B105			1.3	3	1.8
SA3305			5.7	2.7	7.1
A109			3.6	3.3	2
SA341G			3.6	7	2.9
S-65 (CH-53)			3.6	3.5	2.3
UH-60 (S-70)			3.3	7	2.5
S-76			7.5	5.3	5.9
SA365N			4.8	3.6	3.3
SA355F			4.7	4.6	4.4
SA350D			3.6	5.4	2.6
Bell 222			1.5	6.9	3
All	3.72	Avg.	3.59	4.39	3.17
	7.5	Max.	7.5	7	7.1
	1.64	S.D.	1.64	1.56	1.47

Table 2-2

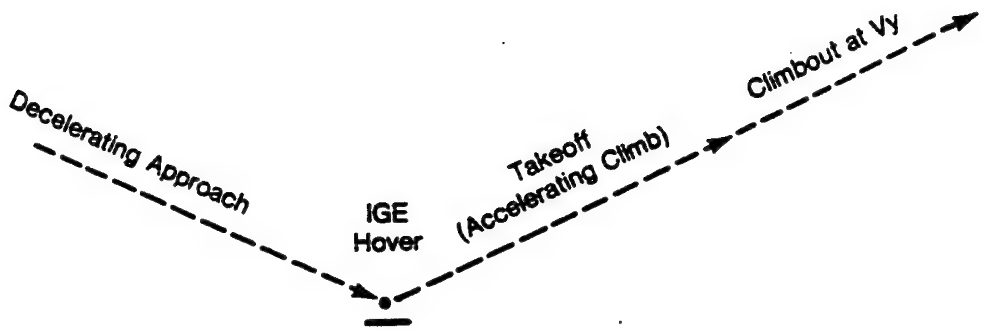
Helicopter Noise Database

Helicopter Type	NOISEFILE Type	NOISEMAP COMDECK No.	Original Source
HH-53	LFO	603	DOT/FAA '79/80
UH-1N	LFO	604	DOT/FAA '79/80
CH-3C	LFO	605	DOT/FAA '79/80
CH-54B	LFO	606	DOT/FAA '79/80
CH-47c	LFO	607	DOT/FAA '79/80
UH-13	LFO	608	DOT/FAA '79/80
TH-55A	LFO	609	DOT/FAA '79/80
OH-6A	LFO	610	DOT/FAA '79/80
AH-1G	LFO/LND/HVR	611	CERL 1992
AH-64	LFO/LND/TKF/HVR	612	CERL 1992
CH-54	HVR	613	CERL 1992
OH-58	LFO/LND/HVR	614	CERL 1992
OH-58D	LFO/LND/TKF/HVR	615	CERL 1992
TH-55	LFO/LND/HVR	616	CERL 1992
UH-1B	HVR	617	CERL 1992
UH-1M	HVR	618	CERL 1992
CH-47B	LFO/LND/HVR	619	CERL 1992
CH-47D	LFO/LND/TKF/HVR	620	CERL 1992
UH-60A	LFO/LND/TKF/HVR	621	CERL 1992
SA350D	LFO/LND/TKF	651	DOT/FAA'90
SA365N	LFO/LND/TKF	652	DOT/FAA'90
SA341G	LFO/LND/TKF	653	DOT/FAA'90
SA330J	LFO/LND/TKF	654	DOT/FAA'90
SA355F	LFO/LND/TKF	655	DOT/FAA'90
A109	LFO/LND/TKF	656	DOT/FAA'90
B212	LFO/LND/TKF	657	DOT/FAA'90
B222	LFO/LND/TKF	658	DOT/FAA'90
CH-47D	LFO/LND/TKF	659	DOT/FAA'90
BO105	LFO/LND/TKF	660	DOT/FAA'90
H500D	LFO/LND/TKF	661	DOT/FAA'90
S-61	LFO/LND/TKF	662	DOT/FAA'90
S-65	LFO/LND/TKF	663	DOT/FAA'90
S-70	LFO/LND/TKF	664	DOT/FAA'90
S-76	LFO/LND/TKF	665	DOT/FAA'90
B206L	–	–	HNM 1.1
B47G	–	–	HNM 1.1
BK117	–	–	HNM 1.1
H300C	–	–	HNM 1.1
R22HP	–	–	HNM 1.1
S-64	–	–	HNM 1.1

(a) Horizontal Flight Profile



(b) Direct Flight Profile



(c) Vertical Flight Profile

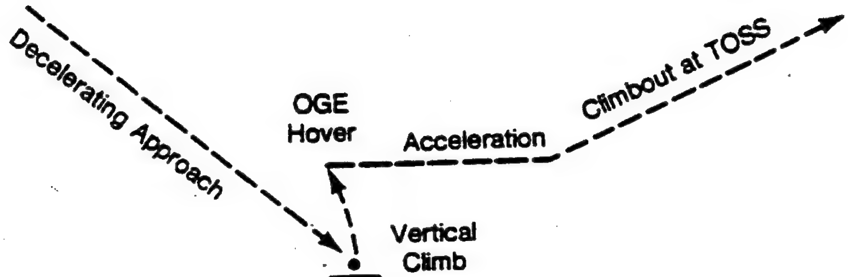


Figure 2-1. Flight Profiles for Heliport Operations (Ref. 14)

for helicopter noise, such as in attempting to develop takeoff and approach noise levels from level flyover data.

Noise data for military helicopters not currently included in any of the available databases may obviously be acquired on an as-needed basis, such as has been the case at MCAS Tustin recently for CH-46 and CH-53E helicopters. This could include data acquired by other U.S. military services and by other NATA services.

The processing by means of OMEGA 6 and OMEGA 8 to provide consistent files would be retained.

2.2 Calculation Procedure Changes

The fundamental "grid-point" noise exposure" calculation method used in NOISEMAP relies on a building block process whereby flight tracks are converted to segmented flight path elements and individually (sequentially) processed to obtain the grid point noise exposure for each type of event. This process can be identically used for helicopter noise, except that the flight tracks will omit runway segments and will often contain vertical ascent or descent elements, and include a larger number of power-setting "SEL-decks" to model arrival and departure procedures.

On the assumption that appropriate reference noise data (i.e., SEL versus distance data) will be available, the following computational processes are applied:

- Create three dimensional flight profile in segments.
- Differentiate between lineal and curvilinear segments.
- Interpolate for SEL at CPA distance from SEL deck.
- Correct for lateral attenuation using air-to-ground and ground-to-ground SEL values, ground incidence angle and a transition factor (lateral attenuation) equation to interpolate between the two SEL values.
- Correct for finite segment length relative to the "infinite line path" SEL value.
- Compute noise exposure contribution due to segment usage by the specific aircraft.

These processes are used for fixed wing aircraft noise estimations and would be identically used for helicopter noise with the following provisos:

- The three-dimensional profiles would include hover, vertical ascent and descent segments.

- Lateral attenuation may be different for helicopter noise due to its tonal (harmonic) content, sometimes impulsive nature, and source configuration (open rotors) which differ from other military aircraft.

- Finite segment corrections may need to take account of the forward or rearward focussed directivity of helicopter noise. (This is in addition to the left/right directivity properties.) Specific examples are given in Ref. 24.

- Smaller grid patterns may be necessary to improve the resolution of noise exposures caused by sharp maneuvers within the base area, and greater dispersion of flight activity over a 360° range.

These provisos are not necessarily critical to the viability of a helicopter noise model, but should at least be examined for their significance in a NOISEMAP framework.

2.3 NOISEMAP Compatibility

A basic question to be addressed is whether, after taking account of the needs associated with helicopter noise exposure calculations, the current NOISEMAP is sufficiently amenable to meeting these needs that its development would be a preferred approach. One alternative is to adopt a different methodology, such as the FAA's HNM, and use it as a parallel processor to NOISEMAP (which would be used only for fixed-wing and ground run-up operations). A hybrid alternative would retain the main operating characteristics of NOISEMAP, including BASEOPS, MCM, NOISEFILE, OMEGA 10 and OMEGA 11, and would incorporate specific helicopter noise calculation revisions where appropriate. This would allow military case studies to be performed using a relatively standardized and unified procedural approach, while helicopter-specific technicalities would be taken care of in the background (of the computational process).

Probably one of the more significant differences between NOISEMAP technology and other program capabilities is that NOISEMAP allows computational features to be added in the frequency domain, that is prior to the OMEGA 10, 11 processing for SEL/EPNL values. Thus

changes to propagation models to include ground or atmospheric impedance variations, or barrier loss estimations, can be introduced in a more fundamental manner in the NOISEMAP programs. This may be of greater importance in military scenarios, where altitude profiles can be unique (such as in nap-of-earth cases).

In terms of computational capability, the existing NOISEMAP is generally compatible with the needs of a helicopter noise model, especially in handling flight track and profile variations via the BASEOPS methodology. While refinements may be needed to such computational elements as

- OMEGA 10 and 11, for propagation,
- LINEX and TURNEX to adjust for finite line and curvilinear flight segments,
- Lateral attenuation, and
- Directivity adjustments (not yet incorporated),

all of the other capabilities are well suited to handling helicopter (and other VTOL) noise cases.

Figure 2-2 summarizes the NOISEMAP process in a simplified form of its application to helicopter and VTOL noise calculations.

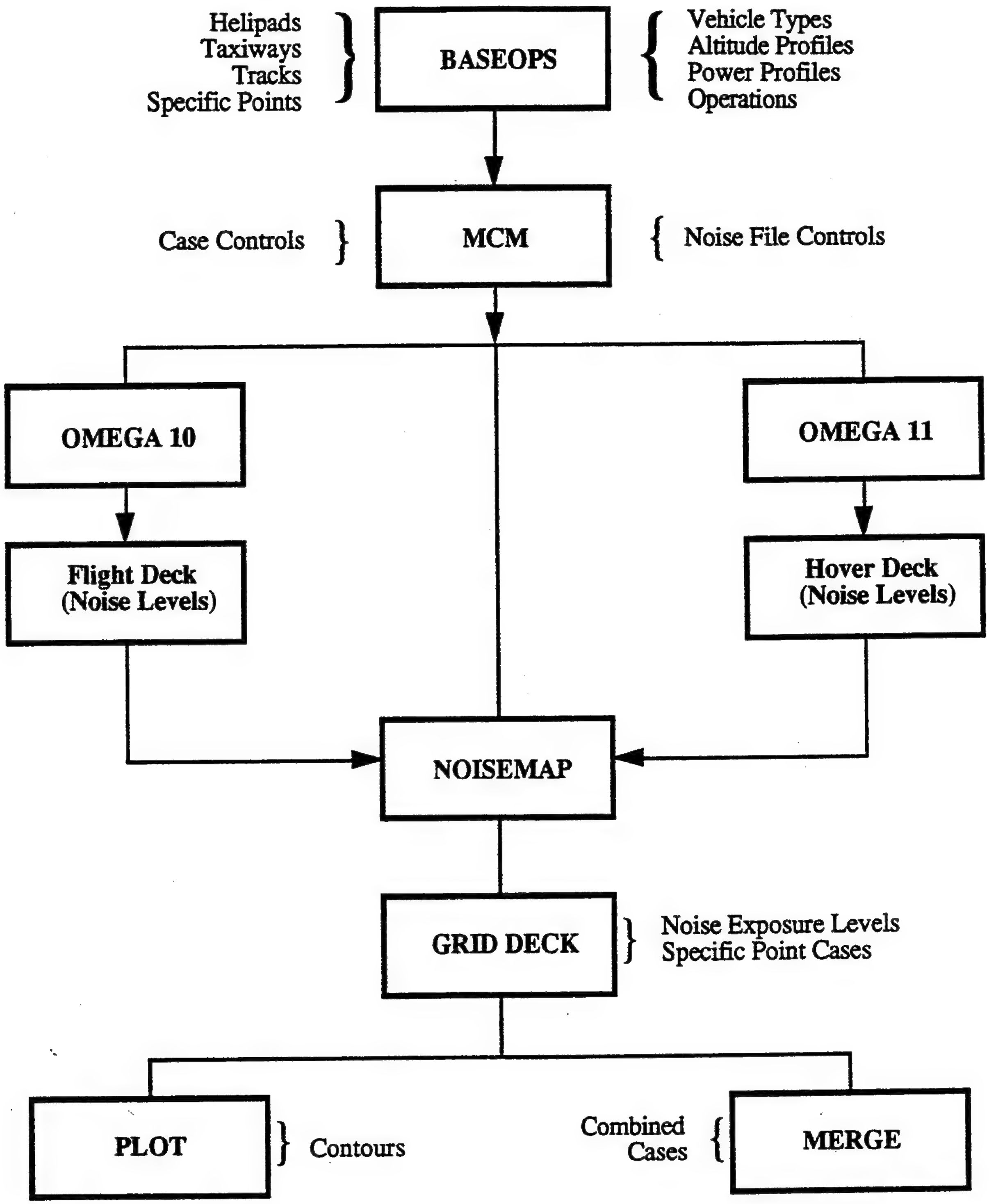


Figure 2-2. NOISEMAP Process

3.0 AVAILABLE TECHNOLOGY

3.1 Heliport Noise Model Technology (DOT/FAA)

HNM is the United States standard procedure for predicting civil helicopter noise exposure in the vicinity of heliports and airports. Version 1 (Ref. 4) was released in 1988, its methodology being documented in a draft report (Ref. 25). An upgraded version (Version 2) is in limited current release for Beta-testing purposes.

The HNM program contains a database of SEL versus (air-to-ground) slant range distance for takeoff, approach, and level flyover conditions, at specified reference flight speeds, for left, center and right side (45°–15°–15°–45°) directions. Additional noise level data is available for Ground Idle (GIDLE), Flight Idle (FIDLE), Hover in Ground Effect (HIGE), and Hover Out of Ground Effect (HOGE) static conditions, in terms of A-weighted Sound Level versus distance over hard or soft ground cover and in terms of directivity pattern definitions and forward speed corrections by means of empirical equations with aircraft specific coefficients. Database 1 covered 21 helicopter types in a limited manner, as illustrated in Table 3.1 (from Ref. 4).

The ultimate intention of HNM is that a wide range of helicopter operating conditions can be modelled by means of the seven sets of noise data, and that these operating conditions can be combined to define operating profiles such as arrivals and departures in a manner somewhat similar to the BASEOPS program for NOISEMAP.

It is evident that a considerable amount of technology development has occurred in the evaluation of the HNM and its database, and that this technology would be of considerable value to the NOISEMAP helicopter noise adaptation. In particular, the following capabilities could be utilized in NOISEMAP.

- Vector conditioning for directivity (left, center, right) processing of noise exposures.

- Velocity-correction effects to noise level data.

- Standardized operating conditions (TKO, APP, LFO, FIDLE, GIDLE, etc.) and default profiles (if applicable to military cases) for departure, landing and en-route flight (although additional profiles would be needed for the military scenario).

Table 3-1

Status Summary of Helicopter Noise Data for Database 1 (Ref. 4)

Order of Storage	Helicopter	Takeoff	Approach	Database Quanties[1]				
				Level Cruise	HOGE[3]	HIGE[3,4]	FIDLE	GIDLE
1	B212	X	X	(1 vel)[2]				
2	S-61	X	X	(1 vel)				
3	S-64							
4	CH-47D (BV234)	X	X	X		DS		
5	H500D	X	X	X		DS		
6	B0105	X	X	(1 vel)				
7	B47G							
8	SA330J	X	X	(1 vel)				
9	B206L			(1 vel)		S		
10	A109	X	X	X		D		
11	SA341G	X	X	(1 vel)				
12	H300C							
13	S-65 (CH-53)	X	X	(1 vel)				
14	S-70 (UH-60H)	X	X	X				
15	S-76	X	X	X		DS		
16	SA365N	X	X	X	S	DS		
17	SA355F	X	X	X	S	DS		
18	SA350D	X	X	X		DS		
19	B222	X	X	X	S	DS		
20	R22HP					D		
21	BK117					D		

1 X indicates data from TSC for Database #1.

2 (1 vel) indicates data available at only on velocity for left, center and right.

3 S means LA versus Slant Distance available from TSC over *soft* ground.
H means LA versus Slant Distance available from TSC over *hard* ground.

4 D means directivity constants available from SWRI for both hard and soft ground.

- Lateral Attenuation models and hard/soft ground cover propagation models.

It is possible that with only some exceptions, the NOISEMAP model for helicopter/VTOL noise exposure calculations could be based on HNM technology. Unique NOISEMAP capabilities such as the OMEGA 10 and OMEGA 11 (frequency-based) computation of noise propagation would be retained as these may be of value to other future technology developments.

Thus while BASEOPS, MCB, OMEGA 10 and OMEGA 11 would be revised versions of their existing form, NOISEMAP calculation features could be adopted, with or without revision, from HNM technology.

3.2 ROTONET Technology (NASA)

The ROTONET computer program is a methodology for the prediction of helicopter noise based on detailed system designs information and prescribed operating parameters. It is the result of a long-term joint program by NASA and industry to predict noise from a range of different aircraft types, including jet, propeller and rotorcraft propulsions. The ROTONET technology has been developed from 1984 to present with Phase IV released in October 1990 (Ref. 27).

The ROTONET system is not considered to be an alternative to NOISEMAP or HNM for purposes of environmental noise level prediction, but provides a capability to create a noise level database for a known or generic helicopter type either in frequency-based format (such as for NOISEFILE) or in a noise level versus distance format (such as for HNM). The system has proven useful in describing the asymmetric characteristics of helicopter noise and may be useful for environmental studies of futuristic cases in long-term projections.

3.3 United States Army Technology (CERL)

The U.S. Army conducts Installation Compatible Use Zone (ICUZ) studies for areas that may be impacted by Army training noise. The most prevalent types of noise in such areas have proven to be blast noise associated with artillery and flyby noise caused by helicopters. The Construction Engineering Research Laboratory (CERL) of the Army has therefore developed a means of predicting such noise exposures in contour form by creating an Integrated Noise Contour System (INCS) containing noise emission data which could be projected over land area maps.

The techniques for helicopter noise prediction are based on the use of a modified version of NOISEMAP, and reference noise level data for Army helicopters as obtained by measurements (Ref. 10, 11, 12). Other capabilities similar to the BASEOPS system have also be developed to measure, monitor or log the occurrence of noise events for Army management purposes, and range-use statistical summaries.

While a detailed review of the Army's version of NOISEMAP has not been accomplished to date, it would appear from the data summary reports that the main features of NOISEMAP have been retained and a simplified input system of flight tracks and profiles is used to simulate the fixed-wing and aircraft noise computation process. This latter procedure is quite simple provided that the required database of noise level, flight profile and operational statistics are known. The input deck for NOISEMAP can be created directly (rather than by MCM, BASEOPS, or by other manual entry methods).

An application of a similar approach has recently used by Wyle staff to generate a noise exposure and noise contour set for the proposed Naval Air Station Fort Worth environmental study. The most difficult problem in this application of NOISEMAP was the creation of sufficient reference noise level data sets to allow a complete landing or departure profile to be described.

It is therefore evident that a cross-reference set of surrogate files needs to be developed if the CERL-type application of NOISEMAP is to be used.

CERL has also committed a considerable amount of research to studies of sound propagation over various types of terrain and in varied atmospheric conditions. This research may be of considerable value in helicopter noise modelling for low altitude (nap-of-the-earth) military operations.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Existing NOISEMAP technology programs can be adapted to provide a capability for helicopter/VTOL aircraft noise impact calculations. These adaptations, involving BASEOPS, Master Control Module (MCM), OMEGA 10 and 11, NOISEMAP and NOISEFILE, are summarized as follows:

4.1 BASEOPS

It is recommended that the BASEOPS program have a separate (selectable) Main Menu applicable to VTOL aircraft. The existing Main Menu for fixed wing aircraft and ground run-up operations would remain unaltered and could also be a selectable option at commencement of BASEOPS.

The VTOL option would create MCM files for VTOL operations as a separate entity, to be dealt with by MCM as a separate individual case (which can subsequently be merged with the fixed wing case at the contour plotting stage).

In addition to General Airfield Data (identical to current format), the General Airfield Data Menu would include:

- Helipad (location) Data
- Taxiway Data (similar to runway data) where appropriate
- Barrier Data (including building facade coordinates and heights)

The Aircraft Operations Data Menu would include:

- Flight Tracks (Arrival, Departure, Closed) identified by an ID number and a Helipad (P) or Taxiway (T) origin.
- Flight Profiles (Arrival, Departure, Closed) which can be cross-referenced to *one or more* flight tracks where operational procedures are identical. A set of default profiles will be available for selection which would be tailored for the specific helicopter type named in the profile description. A set of these is given by example in HNM user's manual (Ref. 4) for civilian operations and would be redefined, if necessary, for military applications.

- Standardized Power Settings, such as TKO, APP, LFO, FIDLE, GIDLE, etc., which can be utilized in defining flight profiles. (Reference noise data for each of these will be created via MCM/OMEGA.)

- Run-up Pad Locations (or helipad identification if used as a run-up facility) and

- Run-Up Profiles (as currently described for fixed wing or engine test facilities, but specific to helicopters or other VTOL aircraft.

Other Menus in BASEOPS would serve the same functions as at present, including

- Print Operations Summary

- Create MCM Files

- Change Current Filename

- Exit

4.2 Master Control Module (MCM)

The MCM controls the usage of data files and programs necessary to obtain a noise exposure grid file and subsequently create noise exposure level contours by means of a plotting routine. For incorporation of a VTOL capability it will only be necessary to add the VTOL status to the MCM menus and provide an option to merge or add the VTOL grid file to a fixed wing (base) grid file for a composite contour plot.

One of the functions of the MCM is to create input decks for the running of OMEGA 10, OMEGA 11 and NOISEMAP programs. These features will be enhanced to be compatible with the revised BASEOPS profile-generators, including the creation of SEL-distance decks for each of the standardized power/flight conditions (TKO, APP, FIDLE, GIDLE, HIGE and HOGE) necessary to describe helicopter operations.

Helipad and taxiway descriptors will be utilized in the NOISEMAP input deck rather than runways (as currently used).

Modification of the MCM program will cause no particular logistical problems.

4.3 NOISEFILE, OMEGA 10, OMEGA 11

As discussed in Section 2, enhancements of NOISEFILE (to include in-flight directivity) and OMEGA 11 (to include hard and soft ground terrain propagation) may be considered for future versions of the helicopter noise calculation process. Similarly, it may be necessary at some future stage to add a metric adjustment capability (although this does not seem likely for U.S. applications) to allow penalties for impulsiveness, signal-to-noise level, rattle-inducement or other subjective characteristics of helicopter noise.

For the Phase 1 version, however, the existing versions of NOISEFILE, OMEGA 10 and OMEGA 11 are adequate for continued use.

4.4 NOISEMAP

Specific functions within the NOISEMAP program have been tailored for error-trapping purposes to ensure fixed-wing aircraft operations are input in an appropriate manner. Some of these are not consistent with helicopter operations and will require revision, such as runway, takeoff roll, track and closed pattern definitions. In most respects, however, the basic form of a NOISEMAP input deck will remain similar to that currently used. The basic input information will comprise:

- AIRFLD descriptor, as currently used,
- PROCES, METRIC, SPROCE and SPECIFIC location descriptions as currently used,
- PAD descriptor (instead of runway),
- FLTTRK descriptors (including taxiways),
- TODSCR descriptors for takeoff (power) profiles (including taxi),
- LANDSCR descriptors for landing (power) profiles (including taxi),
- ALTUDE descriptors for takeoff and landing altitude profiles,
- FLIGHT descriptors for day, night (and evening if CNEL) operations,
- SEL decks for each flight mode (excluding HIGE, HOGE hover),
- RUDSCR for run-up, ground idle, hover

- RUNUP for durations of run-up, ground idle hover in each time period,
- ALDATA files for A-weighted sound level versus distance at each 10 degree azimuth for each power setting.

SEALAT and TOROLL will be inactivated, while a Hover condition will be substituted for takeoff roll static noise and added at final landing condition.

Within the NOISEMAP program, the usage of the above descriptors will be essentially unchanged in the Phase 1 program and will only be changed where absolutely necessary in the Phase 2 program. These will include:

- Creation of three-dimensional flight paths by power, altitude and flight track elements,
- Computation of noise exposure at each grid point, using current versions of LINEX, TURNEX, and Lateral Attenuation,
- Area computation for each specific noise contour value.